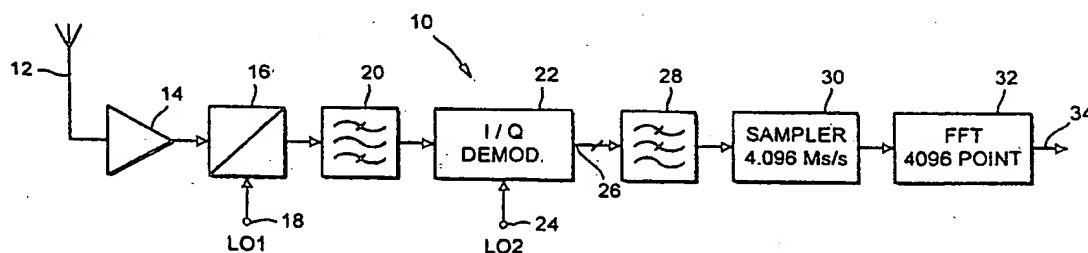




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(54) Title: MULTICARRIER RECEIVER AND METHOD FOR USE IN DAB RECEIVER



(57) Abstract

A digital audio broadcasting (DAB) receiver designed for receiving a signal with 1536 active carriers generated by an inverse fast Fourier transform (FFT) with 2048 points, includes the usual RF stage (14), an IF filter (20), and a demodulator (22). This is followed by an anti-aliasing filter (28), a sampler (30), and an FFT (32). The FFT is a 4096-point FFT, and is thus twice as long as required, and gathers twice as many points during each symbol period. However this is found to substantially simplify the construction of the IF filter (20) and, more particularly, the anti-aliasing filter (28).

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MULTICARRIER RECEIVER AND METHOD FOR USE IN DAB RECEIVER

BACKGROUND OF THE INVENTION

This invention relates to receivers for many-carrier signals, for example OFDM (orthogonal frequency-division multiplex) signals, such as is planned for use in the proposed digital audio broadcasting (DAB) or digital sound broadcasting system, and also in digital television.

One proposal for digital audio broadcasting for use in the United Kingdom requires seven DAB ensembles (channels) each occupying 1.536 MHz within the overall frequency range 217.5 MHz to 230 MHz, a total bandwidth of only 12.5 MHz. The proposed spacing between ensemble centres is 1712 kHz, of which 1536 kHz is taken up by the signal, so that the spacing between the top of one ensemble and the bottom of the next is only 176 kHz. The signal bandwidth of 1536 kHz arises from the use of 1536 separate carriers spaced at spacings of 1 kHz. The number 1536 is chosen as three-quarters of 2048 (equals 2 to the power of eleven).

A DAB receiver must be able to receive the desired DAB ensemble to which it is tuned in the presence of a number of interfering DAB signals occupying the adjacent spectrum. Of the adjacent signals, it is the nearest neighbour which is most difficult to reject because of the high ratio of signal bandwidth to edge spacing; the edge spacing is less than one-eighth of the signal bandwidth.

A typical proposed DAB receiver of this type is shown in schematic block diagram form in Figure 1 of the drawings. The receiver 100 has an antenna 112 feeding a radio frequency (RF) stage shown as an RF amplifier 114.

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To achieve this places considerable demands on the filter 128. This filter should have a pass-band extending to ± 768 kHz (half of 1536 kHz) but a cut-off frequency of ± 1024 kHz (half of 2048 kHz). This is a sharp cut-off and is difficult to achieve. The output 134 of the FFT is a time-based signal which is then processed using conventional receiver circuitry (not shown).

The circuit of Figure 1 will be known to those skilled in the art, and further description thereof is not necessary.

Likewise, a corresponding transmitter will be known to those skilled in the art, and includes a 2048-point inverse FFT operating in the digital domain corresponding to the FFT 132 at the receiver. The inverse FFT receives a conventional time-based signal and converts it into a many-carrier signal for transmission.

Figure 2 is a spectrum diagram showing three adjacent ensembles in the frequency spectrum. The numerical values are those appropriate to the DAB proposal mentioned above, and are referred to the centre frequency of the central ensemble E which is taken to be zero. One ensemble E+1 is shown above this with positive values and another ensemble E-1 is shown below it with negative values. The values are in kilohertz, but as the individual carriers are spaced by 1 kHz, they can equally be treated as a count of carriers. The amplitudes of the signals shown are purely arbitrary; they are shown for convenience of illustration with a slight peak at the centre of each ensemble but in theory the amplitudes should be flat.

It will be seen that each ensemble extends over 1536 carriers, and that the spacing between corresponding points on the ensembles is 1712 carriers.

Figure 2 also shows, for the central ensemble, the positions where the sampling frequency and the inverse appear. These fall at ± 2048 carriers. The values of half

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The FFT circuit 132 expects only 1536 carriers out of a possible 2048, and thus inherently rejects energy in the frequency range 768 kHz to 1280 kHz. This upper limit equals the sampling frequency 2048 kHz minus the expected upper carrier frequency limit of 768 kHz. Within the wanted band, this includes the rejection regions marked R on Figure 3.

We have thus appreciated that to cut out the interference components requires strong IF and anti-alias filtering in the filters 120 and 128 of Figure 1, in order to reject the adjacent channel energy from ensemble E+1 before it reaches the analog-to-digital converter or sampler 130. To produce a sufficiently sharp cut-off may require for example a surface acoustic wave (SAW) filter for use as the filter 128. Such filters are expensive and lossy and may result in the partial loss of a number of carriers located towards the edges of the ensemble. Although the DAB transmission is very robust, nevertheless degrading the signal in this way may reduce the system margins available to combat other sources of degradation, e.g. multipath distortion or channel noise. Other types of filter may introduce less loss of signal but can introduce considerable group delay ripple into the signal. In summary, the filter requirements are quite difficult to meet without simultaneously adversely affecting the wanted signal. This problem arises independently with the IF filter 120 and with the anti-aliasing filter 128, though primarily with the latter.

This problem arises in the analog processing due to the difficulty of making adequately effective filters. It might therefore be thought that the problem could be solved by constructing the filter 128 in the digital domain rather than in the analog part of the circuit. That is to say, the filter 128 (or at least the greater part of its functionality) would be placed after the

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SUMMARY OF THE INVENTION

The invention in its various aspects is defined in the independent claims below to which reference should now be made. Advantageous features of the invention are set forth in the appendant claims.

A preferred embodiment of the invention is described in more detail below, and takes the form of a DAB receiver designed for receiving a many-carrier signal with 1536 active carriers as generated by an inverse fast Fourier transform (FFT) with 2048 points. The receiver has the usual RF stage, an IF filter and a demodulator, followed by an anti-aliasing filter, a sampler, and an FFT device. The FFT is a 4096-point FFT, and is thus twice as long as required, and gathers twice as many points during each symbol period. However, we have found that this enables the construction of the IF filter and, more particularly, the anti-aliasing filter, to be substantially simplified.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in more detail by way of example with reference to the accompanying drawings, in which:

Figure 1 (described above) is a block schematic diagram of the relevant part of a previously-proposed DAB receiver;

Figure 2 (described above) is a spectrum diagram showing three adjacent ensembles of a DAB signal;

Figure 3 (described above) is a spectrum diagram illustrating how the interference is generated;

Figure 4 is a block schematic diagram of the relevant part of a DAB receiver embodying the present invention; and

Figure 5 is a spectrum diagram illustrating how the interference is avoided in accordance with this invention.

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The sampler 30 in this case operates at 4.096 Ms/s, rather than at 2.048 Ms/s as in the system of Figure 1. In the sampler 30 the signals are converted from analog form to digital form, and are then applied to a fast
5 Fourier transform (FFT) circuit 32. The FFT has 4096 points rather than the 2048 points of the FFT 132 in the system of Figure 1. The output 34 of the FFT is a time-based signal which is then processed using conventional receiver circuitry (not shown).

10 Thus the FFT is changed compared with the system of Figure 1, rather than trying to improve the filter 128 directly. This naturally requires a 4096 Ms/s sampler, but has the advantage that the IF filter 20 and the anti-alias filter 28 do not have to have such precise
15 characteristics as the corresponding components in Figure 1. The IF filter can be slightly less narrow as compared to Figure 1, and thus can be of simpler construction. The anti-alias filter 28 still has a pass-band of 768 kHz, but only has to cut-off at 2048 kHz, rather than at 1024 kHz
20 as with Figure 1. Thus although the problem has in principle nothing to do with the FFT, we have found that the problem in filter construction can be solved by making changes to the FFT which follows the filter and sampler, rather than by trying to improve the filter itself.

25 More specifically, as will be described with reference to Figure 5, the longer 4096-point FFT inherently rejects adjacent channel energy in the frequency range between the wanted ensemble edge of 768 kHz and an upper limit of 3328 kHz. This is much
30 wider than the range 768 kHz to 1280 kHz for the system of Figure 1. This increase in the inherent rejection bandwidth greatly reduces the receiver filter requirements, allowing gentler filters to be used, which causes less distortion to the wanted signal. Such
35 filtering is also likely to give rise to lower signal

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above 3328 kHz, which it will be seen, is well above the top of the bandwidth of ensemble E+1.

Thus in the embodiment described, the size of the FFT has been doubled to 4096 points, with a corresponding
5 doubling of the sampling rate. While this is the most convenient value, other values could in theory be chosen, in particular other integral multiples of 2048. This oversampling increases the available processing bandwidth, to allow the IF frequency response (selectivity) to be
10 augmented, while the time period from which the samples are drawn is unchanged.

In general, the system is applicable to a transmission system which has A active carriers out of a possible P carriers, generated by use of a P-point
15 transform. In the receiver, the transform is a Q-point transform, where Q is greater than P. As described Q is greater than 2A and is in fact equal to 2P.

The invention has been described as applied to a DAB receiver, but it can be applied to other receivers for
20 many-carrier transmission systems such as those produced by OFDM systems. Another example is digital terrestrial television, where part of the signal is to be transmitted in OFDM form. The numerical values here are of course different, though the principles are the same.

For example, with the so-called 2k television system
25 as currently proposed, the channel spacing is 4.46 kHz (this being the reciprocal of 224 μ s). The number of carriers used is 1705 giving a total bandwidth of $1.705 \times 4.46 = 7.61$ MHz. The proposed sample rate is
30 9.143 MHz and it is proposed to use a 2048 point inverse FFT at the transmitter and a 2048 point FFT at the receiver. In accordance with this invention as applied to an embodiment for reception of such a television signal, the sample rate is preferably raised, in fact doubled, to

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CLAIMS

1. A many-carrier transmission system, comprising a transmitter which includes inverse transform means for generating from an input signal a many-carrier transmission signal having A active carriers out of a possible P carriers ($A < P$) by use of a P-point transform, the transmission signal consisting of a sequence of symbol periods, and a receiver for receiving the many-carrier signal transmitted by the transmitter, the receiver including:
- means for band-pass filtering and for sampling the received many-carrier signal at a predetermined sample frequency chosen to gather a multiple of P points during one symbol period; and
- transform means for receiving the filtered and sampled many-carrier signal and for generating a time-based signal therefrom;
- in which the transform means at the receiver operates with a Q-point transform where Q is greater than P.
2. A many-carrier transmission system according to claim 1, in which Q is greater than twice A.
3. A many-carrier transmission system according to claim 1, in which Q is equal to or greater than twice P.
4. A many-carrier transmission system according to claim 1, in which P is 2048 and Q is a multiple of 2048.
5. A many-carrier transmission system according to claim 1, in which P is 2048 and Q is 4096.

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11. A method according to claim 8, in which P is 2048 and Q is a multiple of 2048.

12. A method according to claim 8, in which P is 2048 and Q is 4096.

5 13. A method according to any of claims 8 to 12, in which the band-pass filtering and sampling step includes for the band-pass filtering the step of anti-alias filtering the received signal, and for the sampling step sampling the anti-alias filtered signal to supply an output to the
10 transform.

14. A method according to any of claims 8 to 13, in which the transform comprises a Fourier transform.

15 15. A receiver for receiving a many-carrier signal consisting of a sequence of symbol periods, the receiver comprising:

means for band-pass filtering and for sampling a received many-carrier transmitted signal which includes a predetermined number A of active wanted carriers at a predetermined sample frequency chosen to gather a multiple
20 of P points during one symbol period; and

transform means for receiving the filtered and sampled many-carrier signal and for generating a time-based signal therefrom; and

25 in which the transform means at the receiver operates with a Q-point transform where Q is greater than twice A.

16. A receiver according to claim 15, in which Q is 4096.

17. A receiver according to claim 15 or 16, in which the transform means comprises Fourier transform means.

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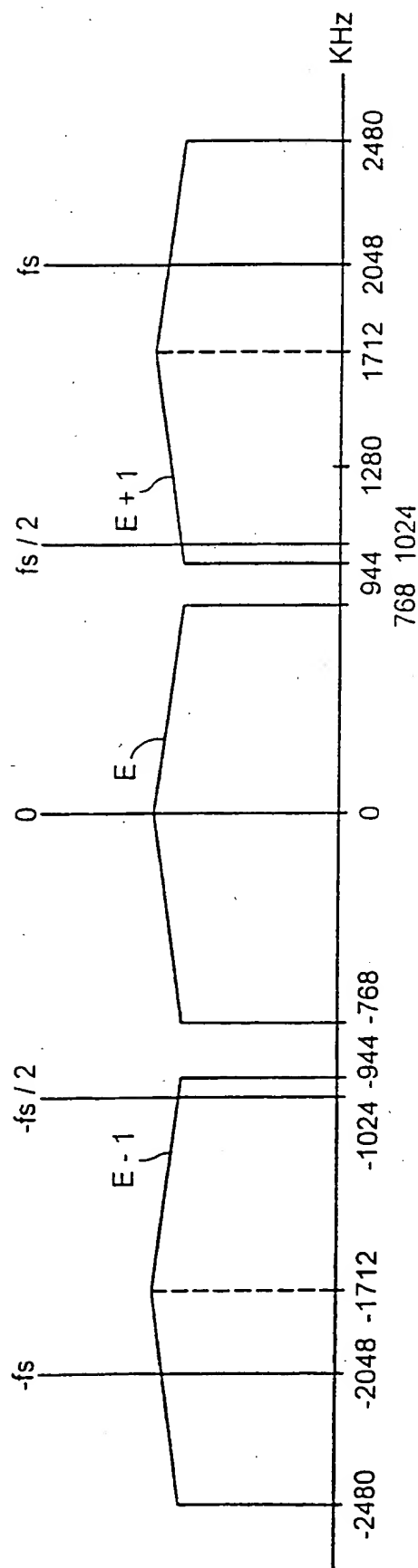
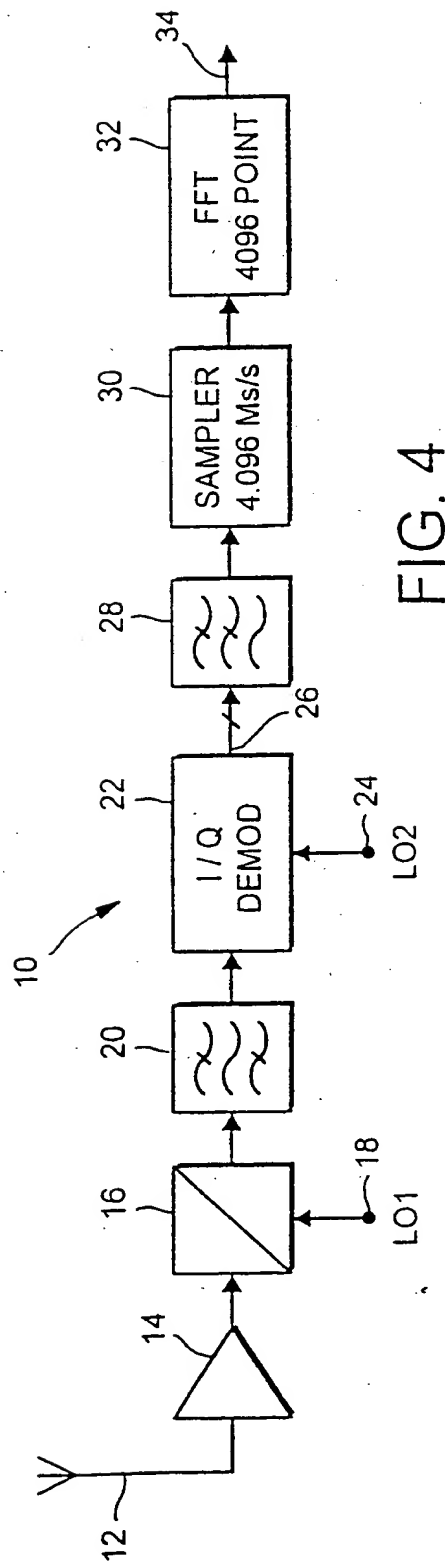


FIG. 2

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INTERNATIONAL SEARCH REPORT

Int. .tional Application No

PCT/GB 98/01299

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 H04L27/26 H04H1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04L H04H H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 195 20 353 A (THOMSON BRANDT GMBH) 12 December 1996 see abstract see column 5, line 54 - line 64 see claims 1,3,6,8 ---	1-17
A	EP 0 613 267 A (PHILIPS NV) 31 August 1994 see abstract see column 6, line 21 - line 57 see figures 4,6 ---	1-17
A	EP 0 641 096 A (FRANCE TELECOM ;TELEDIFFUSION FSE (FR)) 1 March 1995 see abstract see page 11, line 29 - line 49 see figure 7 --- -/--	1,6-8, 13-15,17

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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